AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph at page 1, lines 28-31 of the Specification with the following amended paragraph:

In view of the prior art, there is a need for a planar transmission line to waveguide coupling structure which does not impose constraints on the frequency of operation, and which **[[are]]** **is** relatively inexpensive to manufacture. The present invention is directed to filling such a need.

Please replace the paragraph at page 6, lines 9-26 of the Specification with the following amended paragraph:

Preferred embodiments of coupling structure 20 further comprise one or more capacitive diaphragms 28 which improve the electro-magnetic impedance matching between patch antenna 24 and waveguide 10. One capacitive diaphragm has been shown in FIGS. 1-2. In its most basic form, a capacitive diaphragm 28 comprises a pad of an electrically conductive material disposed within first area 21 and electrically isolated from patch antenna 24, and may comprise the same material as ground ring 22 and/or patch antenna 24. Each capacitive diaphragm is located on bottom major surface 2 or within the substrate layer (as may be the case when the substrate layer comprises sub-layers). A capacitive diaphragm 28 is preferably maintained at a constant potential. It may be electrically coupled to ground ring 22 and/or a ground plane, or it may be fed with a separate potential which is different from ground (in which case it is conductively isolated from ground ring 22). In preferred embodiments of the present invention, at least one capacitive diaphragm 28 and ground ring 22 are electrically coupled together and are integrally formed together with the same material, which provides for a more compact construction of coupling structure. In this preferred implementation, the capacitive diaphragm 28 may contact (*i.e.*, abut **against**) ~~**against**~~ one or more of the sides of ground ring 22, or may be offset from the inner side(s) of ground ring 22 as long as it is electrically coupled (*e.g.*, conductively coupled) to ground ring 22.

Please replace the paragraph at page 7, lines 7-19 of the Specification with the following amended paragraph:

The basic construction of coupling structure 20 further comprises a ground plane 26 disposed on top major surface 3 and over an area of surface 3 which is opposite to at least first area 21. In its most basic form, ground plane 26 comprises a layer of conductive material disposed within this area. In preferred embodiments of coupling structure 20, ground plane 26 is further disposed over an area of surface 3 which overlies ground ring 22. Ground plane 26 aids in the operation of patch antenna 24 by providing the antenna with an opposing grounding surface, and further reduces transmission (*e.g.*, back scattering) of electromagnetic waves from first end 11 of waveguide 10 by providing a conductive shield. When capacitive diaphragm 28 (see FIG. 1) is employed, it is preferably coupled to ground plane 26 by one or more conductive vias 29 formed in or through substrate layer 1 and between its major surfaces 2 and 3. The positions of vias 29 are outlined by dashed lines in FIGS. 1 and 2, and an exemplary one is shown in cross-sectional view by FIG. 3. As seen in FIG. 3, ground plane 26 and capacitive diaphragm 28 are disposed on opposite surfaces of substrate 1, and via 29 is disposed through substrate 1 and between ground plane 26 and capacitive diaphragm 28. As described below in greater detail, FIG. 3 also shows the same structure for a via 39 coupled between ground plane 34 and another ground plane 36, with ground planes 34 and 36 being disposed on **~~the opposite surface~~** **opposite surfaces** of substrate 1, and with the reference numbers 34, 36, and 39 shown within parentheses.

Please replace the paragraph at page 8, lines 3-28 of the Specification with the following amended paragraph:

Because of the perspective angle used in FIG. 2, the output pad on MMIC 8 for signal 4 cannot be directly seen, but is shown in outline by dashed lines in FIG. 2. The pad for signal 4 is coupled to a high-frequency trace 30 by a respective solder bump 7. Trace 30 conveys electrical signal 4 to coupling structure 20, where it is coupled to patch antenna 24 by way of a conductive via 32. The position of via 32 is outlined by dashed lines in FIGS. 1 and 2, and is shown in cross-sectional view by FIG. 4. FIG. 4 shows ground plane 26 and electrical trace 30 disposed on the top major surface of substrate 1; shows patch antenna 24,

capacitive diaphragm 28, ground ring 22, and ground plane 34 disposed on the bottom major surface of substrate 1; and shows a via 32 disposed through substrate 1 and electrically coupled to trace 30 and patch 24. Electrical trace 30 is preferably configured as a planar transmission line, and more preferably as a microstrip line or a coplanar waveguide line. Instead of microstrip line or coplanar waveguide line, preferred implementations of trace 30 may be configured as slot-lines, coplanar strips, and symmetrical striplines, as well as other types of planar transmission lines. As is known in the art, a microstrip line comprises a conductive trace disposed on one surface of a substrate layer, ~~**and**~~ **and a** conductive ground plane disposed on the opposite surface of the substrate layer and underlying the conductive trace. A microstrip configuration for the electrical trace 30 is **[[show]]** **shown** in FIGS. 1 and 2 where the underlying ground plane is shown at reference number 34 in FIG. 1. A grounded coplanar waveguide line comprises the electrical trace and underlying ground plane of the microstrip structure (*e.g.*, trace 30 and ground plane 34), plus additional ground planes on the top surface of the substrate layer, and disposed on either side of the electrical trace. The additional ground planes are shown in dashed lines at reference numbers 36 and 38 in FIGS. 2 and 3. The additional ground planes 36 and 38 are preferably electrically coupled to the underlying ground plane 34 by a plurality of electrically conductive vias 39. Each location of a via 39 is outlined by ~~**dashed**~~ **a dashed** circle in FIGS. 1 and 2, and an exemplary one is shown in cross-sectional view by FIG. 3. As seen in FIG. 3 with the reference numbers shown within parentheses, ground planes 34 and 36 are disposed on opposite surfaces of substrate 1, and via 39 is disposed through substrate 1 and between ground planes 34 and 36. In addition, conductive trace 30 and ground planes 34, 36 and 38 may be formed within substrate layer 1 if substrate layer 1 comprises multiple interleaving sub-layers of dielectric material and patterned conductive material.

Please replace the paragraph at page 9, lines 6-19 of the Specification with the following amended paragraph:

As is well known in the art, the following factors influence the characteristic impedance of trace 30: the dielectric constant and thickness of substrate layer 1, the strip width of trace 30, and the distance of the gap between trace 30 and each of additional ground planes 36 and 38 (if present). One usually has a desired characteristic impedance in mind (usually 50 ohms), and usually has to work with a given substrate layer thickness and dielectric constant. Therefore, one usually varies the strip width of trace 30 and the gap between it and the top-side ground planes 36 and 38 (if present) to achieve the desired level of characteristic impedance. This selection task has been well analyzed in the art, and many college-level books on electromagnetic engineering contain tables and charts which ~~**related**~~ **relate** the trace's strip width to the resulting level of characteristic impedance for a number of transmission line structures. Accordingly, the selection of strip width for trace 30 to achieve a desired level of characteristic impedance is within the ordinary skill of the art and no further explanation need be given here for one of ordinary skill in the art to make and use the present invention.

Please replace the paragraph at page 12, lines 10 - 20 of the Specification with the following amended paragraph:

In our case, we may view waveguide 10 as having a characteristic impedance which we want to match to the characteristic impedance of trace 30. (Methods of determining the characteristic impedance of a waveguide for a ~~**desire**~~ **desired** mode of excitation are well known to the art, as are methods for determining the characteristic impedance of electrical traces.) We then add capacitive reactance at the effective junction between trace 30 and the first end 11 of waveguide 10 to improve the matching between the characteristic impedances. Capacitive diaphragm 28 adds a capacitive reactance to the effective junction point. Increasing the width and/or the area of the diaphragm increases the amount of capactive **capacitive** reactance that is combined with the reactance of the patch antenna, and decreasing the width and/or area will decrease the amount of capacitive reactance.

Please replace the paragraph beginning at page 12, line 21 and ending at page 13, line 3 of the Specification with the following amended paragraph:

One of ordinary skill in the art may use any one of several three-dimensional electromagnetic software simulation programs available on the market to simulate various dimensions of the capacitive diaphragm 28 to provide a desired level of impedance matching. In this way, diaphragm 28 may be used to improve the impedance matching between trace 30 and waveguide 10. As another approach, many of the three-dimensional simulation programs are capable of directly computing scattering parameters which are representative of the ~~amount~~ **amount of** signal reflected back to MMIC 8 and of the degree of transmission from MMIC 8 to waveguide 10. Several simulations may be conducted using different dimensions for patch antenna 24 and diaphragm 28 to determine a set of dimensions which provides a low amount of reflection (low magnitude of scattering parameter S_{11}) and a high degree of transmission (high magnitude of scattering parameter S_{21}) at the desired operating frequency. Usually, lowering scattering parameter S_{11} will result in an increase in scattering parameter S_{21}, and therefore the search for appropriate dimensions is relatively simple.

Please replace the paragraph at page 13, lines 8-24 of the Specification with the following amended paragraph:

FIG. 6 shows a plot of the magnitudes of simulated scattering parameters S_{11} and S_{21} for an exemplary coupling structure 20 constructed for an operating frequency of 76 GHz, with trace 30 configured as a 50-ohm microstrip line (additional ground planes 36 and 38 are not used). The magnitude of S_{11} is proportional to the magnitude of the portion of signal 4 which is reflected from the waveguide back to MMIC 8 divided by the magnitude of signal 4 as initially generated by MMIC 8. The magnitude of S_{21} is proportional to the magnitude of the wave transmitted through waveguide 10 from its first end divided by the magnitude of signal 4 as initially generated by MMIC 8. The magnitudes of parameters S_{11} and S_{21} range between 0 ($-\infty$dB) and 1.0 (0 dB), and are often given in units of decibels (dB). As a general rule, S_{21} decreases as S_{11} increases, and S_{21} increases and S_{11} decreases. A magnitude of S_{11} near zero, and a magnitude of S_{21} near 1 indicate a good impedance match. Referring to FIG. 6, it can be seen that at the operating frequency of 76 GHz the transmission scattering

parameter S21 is near 0 dB (which ~~corresponding~~ corresponds to 1.0), and the reflection scattering parameter S11 is close to -40 dB (which corresponds to $1x10^{-4}$). Thus, the return loss at 76 GHz is substantially 40 dB. As can be seen in FIG. 6, there is a 15-dB return loss bandwidth of approximately 2 GHz centered about the operating frequency of 76 GHz.

Please replace the paragraph starting at page 14, line 15 and ending at page 15, line 5 of the Specification with the following amended paragraph:

The device of Example 2 is similar to the device of Example 1 except for the following differences:

- Two capacitive ~~diaphragm~~ diaphragms 28′ and 28″ are used. They are disposed symmetrically on both sides of patch antenna 24, in the locations shown in FIG. 5. Each diaphragm 28′, 28″ is 3.1 mm long, and 0.150 mm wide.
- Patch antenna 24 has the dimension of 1.88 mm by 1.036 mm.
- Via 32 is located such that it makes contact to a point within the rectangular perimeter of patch antenna 24, the point being 200 μm from the perimeter of the patch antenna. Like the previous example, Via 32 is centered along the width dimension of patch antenna 24. The aperture diameter for via 32 is 200 μm.
- Trace 30 has a tapered width over a 1.5 mm section of its length, the section being located near the end where it couples to via 32. Near MMIC 8, trace 30 has a width of 250 μm (which provides a 50 ohm characteristic impedance), and near via 32 it has a width of 400 μm.

FIG. 7 shows a plot of the magnitudes of simulated scattering parameters S_{11} and S_{21} for the example 2 device constructed for an operating frequency of 76 GHz. From the figure it can be seen that at the operating frequency of 76 GHz the transmission scattering parameter S21 is near 0 dB (which ~~corresponding~~ corresponds to 1.0), and the reflection scattering parameter S11 is close to -22 dB (which corresponds to $3.2x10^{-3}$). Thus, the return loss at 76 GHz is substantially 22 dB. As can be seen in FIG. 7, there is an 11-dB return loss bandwidth of approximately 2 GHz centered about the operating frequency of 76 GHz.

Please replace the paragraph at page 15, lines 6-14 of the Specification with the following amended paragraph:

Accordingly, it may be appreciated that the coupling structures according to the present invention can provide high transmission efficiencies from planar transmission lines to waveguides with very low return losses within a desired transmission bandwidth. In addition, the components of the coupling structure may all ~~**before**~~ **be** formed on the major surfaces of a substrate, which provides a very compact coupling structure ~~**which**~~ **that** is very inexpensive to construct with ~~**present day**~~ **present-day** circuit board construction processes, and which can be readily attached to an end of a waveguide without the need for structural modifications. As a result, the manufacturing and packaging costs of the coupling structure are significantly reduced over those of prior art coupling structures.

Please replace the paragraph at page 15, lines 15-16 of the Specification with the following amended paragraph:

The present invention enables the achievement of a completely planar ~~**coupled**~~ **coupling** structure for coupling between planar transmission lines and waveguide.

Please replace the Abstract at page 23 with the following amended Abstract:

Disclosed are planar structures for coupling electromagnetic signals between planar transmission lines and waveguides. A preferred exemplary structure comprises a shielded patch antenna and one or more capacitive diaphragms disposed adjacent to the patch antenna. This structure is advantageous to MMIC modules in connecting from a planar transmission line of a substrate carrying an MMIC to an external waveguide without the need of a non-planar back metal short, which is normally essential to avoid back scattering from **the** waveguide and also normally needed to achieve impedance matching. In structures according to the present invention, a patch antenna radiates into the waveguide while the antenna's ground plane reduces back scattering from **the** waveguide. The one or more capacitive diaphragms provide impedance matching between the microstrip and the waveguide.